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TRANSLATION-GLIDING IN CRYSTALS

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ABSTRACT

In the absence of any treatment of translation-gliding in English, this paper is presented as an introduction to forthcoming experimental and theoretical contributions to our knowledge of that subject. The fundamental concepts are discussed, and a tabulation of existing data and literature appended.

INTRODUCTION

The plastic deformation of crystals, judging by the literature, appears to be a subject of very remote interest to most crystallographers and mineralogists. The crystallographic investigations along this line have been carried on mainly by our more academic German contemporaries, especially by Mügge and Johnsen. On the other hand the metallurgists have, of late, deluged their literature with a large mass of data, accompanied by encouraging crystal structure explanations, bearing on the plastic deformation of metal crystals. While this branch of crystallographic metallurgy is still in its infancy, enough evidence has been brought forward to demonstrate that the plastic properties of metals are dependent upon, and to a remarkable degree, predictable from their respective crystal structures.

Not so much, unfortunately, can be said about our state of knowledge regarding the mechanism of plastic deformation of crystals other then metals. The investigations have been concerned mainly with mineral crystals, and most of them were on record before the advent of crystal structure analysis in 1912. These publications accordingly contain no crystal structure interpretations of the experimental observations recorded, nor have more recent papers attempted to give structure explanations of these earlier results. Except in a few cases of twin-gliding, subsequent observations have likewise been unaccompanied by discussions of structural significance.

The mineralogist may well study this field, not only to cast light upon the nature of crystal structure, but also because an understanding of the plastic flow of crystals is fundamental to an understanding of the plastic flow of rocks, and, in part, probably causally connected with recrystallization. Early concepts ascribed the changes of metamorphism to differential pressure, temperature, and recrystallization. More recently, it has been in vogue to discount these processes in favor of metasomatic exchange of fluid constituents, so much so, that the possibilities of the earlier ideas are perhaps not fully appreciated. It has been found that metals are constrained to recrystallize by reason of plastic flow and subsequent annealing, and the geologist would do well to study this question for his own peculiar applications.

Since no systematic treatment of the plastic properties of crystals has appeared in English, the present paper is presented to offer an introduction to several experimental and theoretical contributions which follow. Only that plastic mechanism to be designated as "translation-gliding" will be considered.

GENERAL FEATURES OF TRANSLATION-GLIDING[1]

TWIN-GLIDING AND TRANSLATION-GLIDING. Plastic deformation mechanisms may be grouped into two major divisions, twin-gliding and translation-gliding. Twin-gliding is a clearly defined single mechanism while translation-gliding really includes several closely related phenomena. Twin-gliding involves a translatory movement of one part of a crystal in such a manner that this resulting deformed portion takes the relation of a twin to the remaining portion of the original crystal. In general, the crystallographic orientation of the twinned part has been altered in a regular manner prescribed by the corresponding twin law, and thus the slipping movement must be equally distributed in amount throughout the deformed crystal part.

Translation-gliding is a slipping process of *indefinite* magnitude which may take place between two portions of certain crystals. It differs from twin-gliding in that the magnitude of the slip may differ for various structural planes of the same attitude, and in that, if the crystallographic orientations of the individual slipping blocks are altered at all, they are irrationally altered and thus do not take the relation of twins to one another. Since several distinct processes may be involved, these will be discussed under their respective titles for clearness.

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[1] A. Johnsen, Die Struktureigenschaften der Kristalle: *Fortschritte der Mineralogie*, etc., **3**, 1913, pp. 100–110.

A. Johnsen, Schiebungen und Translationen in Kristallen: *Jahrbuch der Radioaktivität und Elektronik*, **11**, 1914, pp. 248–259.

PURE TRANSLATION. Pure translation is the simplest of translation-gliding processes. It involves a slip between two adjacent portions (blocks or sheets) of the crystal in such a manner that corresponding crystallographic elements remain parallel in each block (Figure 1). The planes along which the gliding takes place are designated by the symbol *T*, and the direction of movement by the symbol *t*. In all cases, both *T* and *t* are rational crystallographic elements.

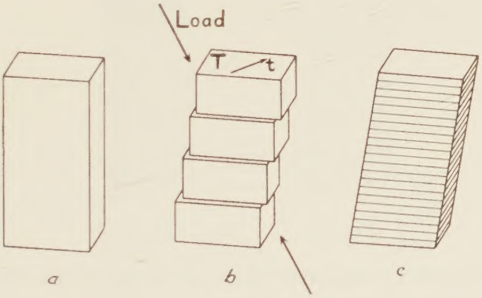

FIG. 1.

The determination of *T* is rather easily accomplished on a given deformed crystal; *t* is more difficult to obtain. To the first approximation, it may be said that translation takes place by block slipping (important exception to this is discussed elsewhere).[2] That is, the applied pressure forces blocks of the crystal to slip past one another without loss of continuity, the planes delimiting the blocks and along which the shear is localized being *T*. In general, natural crystal faces or ground-on surfaces not parallel to *t* will be found, after deformation, to be covered with striations marking the traces of *T* on those particular surfaces (Figure 1). These striations are exceedingly minute and must be searched for with high-magnification binoculars. Using a sharp (rather than diffused) light source, the steps between blocks and the blocks themselves, appear as thin striae marked by difference in intensity of illumination.

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[2] M. J. Buerger, The Cause of Translation Striae and Strain-hardening in Crystals: *Proc. Inst. Metals Division, A. I. M. M. E.*, **1928**, pp. 385–386.

Knowing its traces on the crystal surfaces, T may be identified by inspection, in simple cases, by merely noting what crystallographic face is parallel to all these traces. In more complex cases, especially in crystals of systems other than cubic, simple calculations may be necessary to establish T.

Surfaces parallel to t necessarily remain free from striations (Figure 2). This circumstance provides one of the two methods of determining t[3] (for the other method, see under Bend-gliding, p. 50); t is obviously the axis of the zone containing the plane T and those (other) faces free from striations. Thus, knowing these, t may be determined by inspection, or by the usual cross-multiplication of the symbols of the striation-free faces, one of which may be T.

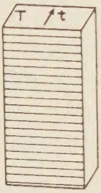

FIG. 2.

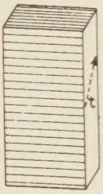

FIG. 3.

It not infrequently happens that no faces of the deformed crystal are striation-free because a face parallel to t is not developed on the particular specimen in question. In experimental deformation, the remedy for this condition is to grind an artificial surface on a new crystal parallel to one of the possible translation directions or to seek a new crystal having this plane naturally developed. This direction, t, of course, will be some simple rational direction in the translation plane, so the possibilities are limited to only a few, usually two, directions. If deformation of this new specimen leaves the selected surface striation-free, the possibility chosen was the correct one.

It should be noted that, generally speaking, the plane T must be established by at least two non-parallel sets of traces. Thus, in the example shown in Figure 3, both T and t are indeterminate since the two sets of striations are parallel. In experimental work this condition may be remedied either by selecting a crystal for further testing which is rich in forms, or by grinding artificial facets of the desired attitude on less desirable material, such as cleavage pieces.

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[3] O. Mügge, Ueber Translationen und verwandte Erscheinungen in Krystallen: *Neues Jahrbuch für Min.*, **1898**, I, p. 72.

In isometric crystals *T* may also be identified by the fact that about the slip planes a slight anisotropism becomes localized.[4] It has been assumed in certain quarters that one of the principal axes of the indicatrix of the resulting anisotropism corresponds with *t*, and this assumption appears very reasonable, indeed, from structural considerations, but this criterion for the determination of *t* has not always been judiciously applied. In crystal systems other than isometric the birefringence is correspondingly slightly altered along translation planes.

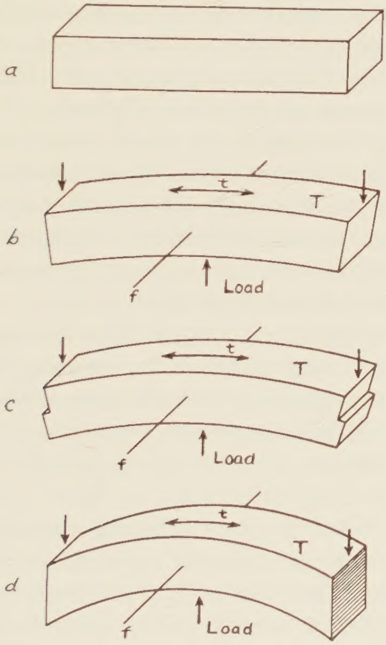

FIG. 4.

Crystals of high symmetry offer complications in the determination of the translation elements since frequently all crystallographically equivalent translation planes slip simultaneously, or because a plane may, when symmetrically loaded, simultaneously slip in several equivalent directions. Each crystal kind presents a problem unto itself.

[4] See p. 51; also M. J. Buerger, *op. cit.*, p. 387 and 388.

Bend-gliding (*Biegegleitung*). Bend-gliding is a heterogeneous process, including at once elastic and plastic deformations. If a crystal is capable of easy translation, it may be perceptibly bent about an axis which lies in the translation plane and normal to *t*. The mechanism is pictured in Figure 4. Up to the limit of pure elasticity (which can not clearly be observed by simple inspection) the crystal subjected to bending stresses has its concave surface under compression and its convex surface under tension (Figure 4*b*). According to the principles of mechanics, a longitudinal shear is developed in the translation planes under these circumstances, and provided translation is sufficiently easy that it occurs before actual rupture of the crystal, the elastic strain is partially relieved, upon application of further stress, by translation along *T* (Figure 4*c*). The crystal thereafter remains permanently bent even though the causal external forces are removed. Examination of the crystal reveals traces of the translation planes as numerous fine striae on faces not parallel to *t* (Figure 4*d*).

It should be noted that each little layer bounded by translation planes is itself still under elastic strain, although the original strain between it and its neighboring layers has been relieved and reversed in direction by the plastic process, translation. Furthermore, the translatory movement is zero at some point in the bend (at the center of the idealized illustration in figure 4, *c* and *d*), and of finite value at other points, becoming cumulatively larger the greater the distance from the zero point. Thus, not only the bend-gliding as a whole, but the translation itself is heterogeneous in character. Further, a boundary of a unique sort exists between adjacent, bent translation blocks. On one side of the boundary, the face of the block under tension is stretched, on the other, the face of the layer under compression is contracted, so obviously the crystal units on either side of the operative translation planes are periodically in and out of phase or continuity with one another, even though the crystal itself remains optically clear and although the crystal faces parallel to *t* show no visual evidence of discontinuity. The forces residing in or about this boundary are responsible for maintaining the crystal in its bent condition.

Stibnite, cyanite and gypsum show bending to a remarkable degree. Cyanite, prepared for student use in optical crystallography by grinding through 100-mesh, may frequently be observed under the microscope to have been bent into a semicircle in the process of crushing, while gypsum, in the form of a thin cleavage flake, may be bent into a complete cylinder.

Bend-gliding not only occurs in a directed attempt to produce it, but usually is an incidental accompaniment of attempts to produce pure translation. This results from the application of a non-uniform or eccentric load. Doubtless the peculiar boundary surface produced in bend-gliding contributes to the anisotropism of the translation planes of isometric crystals. In the experimental stretching of metal single crystal wires, bend-gliding is invariably present due to the varying rotations of the different slipping blocks.

When two flexible sheets in contact are bent about an axis so that slip occurs between them, the contraction on the concave sides of the sheets takes place in a direction normal to, and toward, the axis of bending, and the expansion of the convex sides of the sheets likewise takes place in a direction normal to, but away from, that axis. Consequently the direction of the shear between the sheets, which is the moment of their respective, adjacent contraction and expansion in the slip surface, necessarily occurs in a direction normal to that axis also. Thus if the direction of the shear is specified in a plane between two sheets, the bending axis is known to lie in that plane and at right angles to the shearing direction, or conversely, if the bending axis is known, the direction of slip is fixed.

This circumstance supplies the other method of determining *t*. In certain cases it is useful, but in others it may be misleading or confusing. This happens when slip may occur in several directions at once, in which case the surface of the crystal may present a confusingly warped appearance; or other planes at angles to the one under observation may also function as slip planes, in which case these may produce a meaningless apparent bending of the latter. This possibility may be disregarded if the surface under observation is definitely striation-free.

The bending axis or folding axis is designated by the symbol *f*. Since it perforce lies normal to *t* in *T*, it need not necessarily be a rational crystallographic direction.

TWIST-GLIDING. Certain crystals are capable of undergoing a considerable amount of plastic twisting about a torsion or twisting axis, τ. With the exception of NH_4Cl and NH_4Br, the known crystals characterized by this property are of relatively low symmetry, possibly because if the phenomenon occurs in crystals of high symmetry its presence is masked by other plastic processes taking place simultaneously in numerous equivalent directions. NH_4Cl and NH_4Br are unique, among crystals of high symmetry, in having only three equivalent translation directions, and these at right angles, so that one translation direction can function independently of the others.

The mechanism of the process is but poorly understood. After twisting, the crystal displays the striations characteristic of translation along T parallel to t (Figure 5). The planes, T, farthest from the twisting axis would normally be lengthened the most by twisting, so they apparently slip relative to those nearer the axis and in this contraction thus tend to relieve the stretching effect. Faces not in the zone τ show, after deformation, a duplex warping. Curvature about one axis is due to different requirements of slip for planes at various distances from the central slipping axis; the other curvature appears to be related to an actual distortion of the slip planes (See Figure 6).

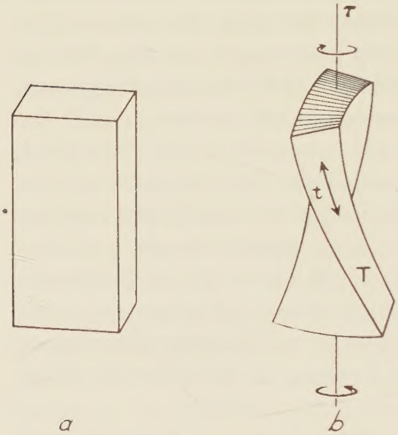

FIG. 5.

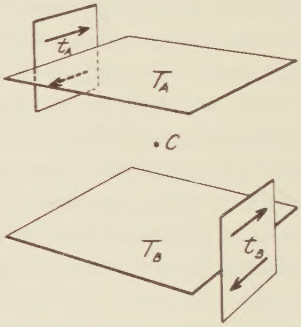

FIG. 6.

TRANSLATION-SYMMETRY. From a gross point of view, if a crystal is capable of translation along a plane $T=(hkl)$ in a direction $t=[uvw]$, it may slip along any plane of the family of planes having the attitude with respect to the crystallographic axes indicated by (hkl) regardless of central distance. This is diagrammatically shown in figure 6, in which translation is simply represented by its essential quality, a shearing couple, the direction of the arrows representing the differential displacement of translation thus being drawn parallel to t; the plane of the couple is conveniently represented as normal to T, but this is not necessary for a general demonstration. If T_A slips, any other parallel plane, T_B, may do so in a corresponding manner and in the same sense. Thus, between the two sets of vectors indicative of the translation process, a center of symmetry, C, is introduced. In other words, translation processes are centro-symmetrical, considered from a point-group, symmetry viewpoint, and in finding the number of equivalent translation planes of a given crystal, its point group must be multiplied by a symmetry center. A number of the crystal classes unite through this multiplication process, reducing the 32 crystal classes to 11 centro-symmetrical groups.[5] The 32 point groups unite to form the 11 centro-symmetrical groups as follows:

Crystal System	Centro-Symmetrical Group	Included Point Groups		
		Schoenflies' Symbol	Roger's Symmetry Formula[6]	Roger's Number[6]
Triclinic	S_2	C_1	No symmetry	1
		S_2	C	2
Monoclinic	C_2^h	C_2	A_2	3
		C_1^h	P	4
		C_2^h	$A_2 \cdot \mathrm{P} \cdot \mathrm{C}$	5
Orthorhombic	V^h	V	$3A_2$	6
		C_2^v	$A_2 \cdot 2P$	7
		V^h	$3A_2 \cdot 3\mathrm{P} \cdot \mathrm{C}$	8
Tetragonal	C_4^h	S^4	$\overline{AP_4}$	9
		V^d	A_4	10
		C_4^h	$A_4[\overline{AP_4}] \cdot \mathrm{P} \cdot \mathrm{C}$	13
	D_4^h	C_4	$\overline{AP_4} \cdot 2A_2 \cdot 2P$	11
		D_4	$A_4 \cdot 4A_2$	12
		C_4^v	$A_4 \cdot 4P$	14
		D_4^h	$A_4[\overline{AP_4}] \cdot 4A_2 \cdot 5\mathrm{P} \cdot \mathrm{C}$	15

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[5] Theodor Liebisch, *Grundriss der Physikalischen Krystallographie, Leipzig*, **1896**, pp. 180–181.

A. Johnsen, Die Struktur eigenschaften der Krystalle. *Fortschritte der Mineralogie*, etc., **3**, 1913, p. 137.

[6] Austin F. Rogers, A Mathematical Study of Crystal Symmetry: *Proc. Am. Acad. Arts & Sci.*, **61**, 1926, p. 200.

A Tabulation of the 32 Crystal Classes: *Am. Mineralogist*, **13**, 1928, p. 571.

Crystal System	Centro-Symmetrical Group	Included Point Groups		
		Schoenflies' Symbol	Roger's Symmetry Formula[6]	Roger's Number[6]
Hexagonal	C_3^i	C_3	A_3	16
		C_3^i	$\overline{AP}_6(C)$	17
	D_3^d	D_3	$A_3 \cdot 3A_2$	18
		C_3^v	$A_3 \cdot 3P$	19
		D_3^d	$\overline{AP}_6 \cdot 3A_2 \cdot 3P(C)$	20
	C_6^h	C_3^h	$\overline{CA}_6(P)$	21
		C_6	A_6	23
		C_6^h	$A_6[\overline{AP}_6][\overline{CA}_6](P)(C)$	25
	D_6^h	D_3^h	$\overline{CA}_6(P) \cdot 3A_2 \cdot 3P$	22
		D_6	$A_6 \cdot 6A_2$	24
		C_6^v	$A_6 \cdot 6P$	26
		D_6^h	$A_6[\overline{AP}_6][\overline{CA}_6](P) \cdot 6A_2 \cdot 6P(C)$	27
Isometric	T^h	T	$4A_3 \cdot 3A_2$	28
		T^h	$4\overline{AP}_6 \cdot 3A_2 \cdot 3P \cdot (C)$	30
	O^h	O	$3A_4 \cdot 4A_3 \cdot 6A_2$	29
		T^d	$3\overline{AP}_4 \cdot 4A_3 \cdot 6P$	31
		O^h	$3A_4[3\overline{AP}_4] \cdot 4\overline{AP}_6 \cdot 6A_2 \cdot 9P \cdot (C)$	32

ONE-SIDED GLIDING. A curious consequence of symmetry is that, unless one of the proper elements is present in a special space relation to T and t, the translation itself may be one-sided. The only symmetry element necessarily involved in translation is a center, and conversely if the process of translation is operated upon by a symmetry center, only translation in its original sense results. Thus, in Figure 6, the translation couple in T_A is clockwise, and the symmetry center, C, reproduces it correspondingly clockwise in T_B.

Under each of certain conditions of specific, possible space relationship between the translation elements and the symmetry elements of the point-group of a crystal, the translation direction automatically loses the general characteristic of rotational sense, and becomes "two-sided." The possible relations which give rise to "two-sidedness" are:

(*a*)[8] An even-fold symmetry axis parallel to *t* (Fig. 7).
(*b*)[7] A symmetry plane normal to *t* (Fig. 8).
(*c*)[7] An even-fold symmetry axis normal to *T* (Fig. 9).
(*d*) A symmetry plane parallel to *T* (Fig. 10).

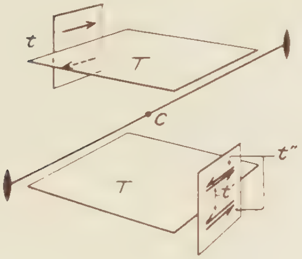

FIG. 7.

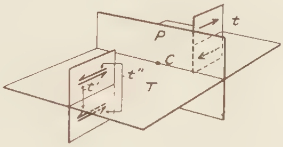

FIG. 8.

In each of the figures, the symmetry center, *C*, reproduces the initial couple, *t*, in its original sense, *t'*, while the other symmetry element simultaneously reproduces it in the opposite sense, *t''*. This new, double couple generated by symmetry therefore, lacks a rotational sense, and consequently translation must take place with equivalent ease in either direction. In order to avoid confusion, the indicated symmetry operations in the illustrations have not been completed.

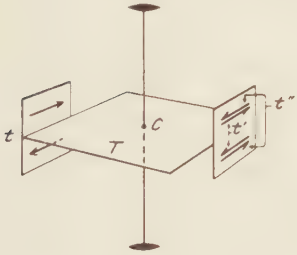

FIG. 9.

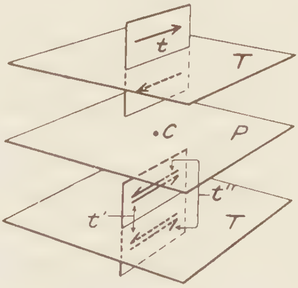

FIG. 10.

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[7] After his experimental discovery of one-sided translation-gliding in $BaBr_2 \cdot 2H_2O$ these two relationships were implicitely set forth by O. Mügge, Ueber Translationen und verwandte Erscheinungen in Krystallen: *Neues Jahrbuch*, **1898**, I, pp. 112–113.

[8] This relationship, in addition to those of Mügge, was recognized by A. Johnsen, Schiebungen und Translationen in Kristallen: *Jahrbuch der Radioaktivität und Elektronik*, **11**, 1914, p. 256.

Due to the centro-symmetrical character of translation-gliding, the translation-gliding group, *a*, is identical with *b*, and similarly *c* is identical with *d*, as indicated by the brackets. The accompanying figures have been particularized for simplicity; if these are redrawn in a general fashion (using a general position for both translation plane and translation direction, and employing a random angle between the plane of the translation couple and the translation plane) it will be evident that the bracketed relations involve each other. Thus, whether Mügge was aware of the fact or not, his conditions for two-sided gliding[9] embrace all possible ones.

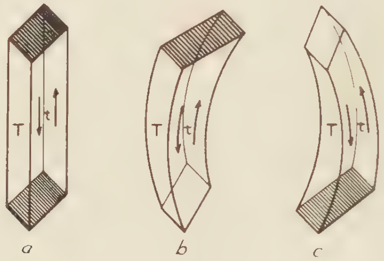

Fig. 11.

One-sided translation-gliding is most easily observed in bend-gliding, especially in monoclinic crystals lacking the above mentioned two-sided translation conditions. For example, with $T=(100)$, $t=[001]$, $f=[010]$ as shown in Figure 11, if the crystal is bent convex forward, the translation couple sense being counterclockwise as seen in the figure, striae appear only at the top (Fig. 11*b*). If it is bent concave forward, striae appear only at the bottom (Fig. 11*c*). Both $BaBr_2 \cdot 2H_2O$ and low-$KClO_3$ offer excellent illustrations of one-sided gliding. In both examples, a family of planes in the *b*-axis zone may be readily sheared counterclockwise as viewed from the positive end of the *b*-axis, but translation-gliding is impossible in the reverse sense. On the other hand, cyanite and $KMnCl_3 \cdot 2H_2O$, crystals whose triclinic symmetry, in the strictest sense, require non-equivalence of translation senses, apparently glide with equal ease in both senses. Doubtless even here there is a real difference in gliding ease which is only inappreciable because of the lack of sensitivity of the methods of investigation.

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[9] Mügge, as well as Johnsen, actually stated conditions under which one-sided gliding was to be expected. They implied, of course, two-sided gliding under conditions which were excluded for one-sided gliding.

TRANSLATION-GLIDING CRITERIA. Since both translation-gliding and twin-gliding processes give rise to striations which may resemble one another very closely on superficial examination, methods other than simple inspection must usually be resorted to in order to distinguish between these two types of gliding. All such methods are based upon the general principle that twin-gliding changes the orientation of the parts of the crystal affected according to a definite twin-law, while translation-gliding either does not change the orientation of the affected part, or, in the case of bend-gliding, changes them continuously and irrationally.

Probably the simplest means of distinguishing these processes is by etching. Having determined the plane and direction of gliding, the crystal is ground and polished parallel to any random or predetermined face and etched with some suitable reagent. Twinning then becomes apparent as a grating or plaid etch pattern, showing up twinned and original portions of the crystal in contrast because their different orientations on the polished face react with different degrees of rapidity to the etchant. As a rule, the slower the action of the etchant (by dilution, for example) the greater the contrast between the twins. Since translation-gliding does not change the orientation of adjacent slip blocks, etching produces a uniform etch on a crystal deformed by this mechanism.

A somewhat more elaborate criterion may be had by goniometric measurement. The angle between the sides of the grooves, which give the visible appearance of striations due to difference in intensity of light reflected by them to the eye, is characteristic of the twin law, and the sides of the grooves are facets which yield reflections as good as the original faces, except as their decreased size effects the image. Translation, on the other hand, proceeds with a different intensity along the various possible T planes of a family, thus changing any originally smooth face (except one parallel to t) to a minutely undulating one, with the result that the reflection from this face is broken up, or drawn out over a range.

Twin-gliding in anisotropic crystals may often be established by the change in optical orientation of the resulting twin lamellae, but this criterion, while definite, should be used with caution because of possible confusion with the slight change in anisotropism which appears along translation planes in translation-gliding.

If the gliding plane is parallel to a symmetry plane, twin-gliding may be disregarded as a possibility and the deformation ascribed to translation-gliding.

Such criteria are not always necessary. It may be perfectly obvious that twin-gliding has taken place when a large secondary twin is produced (e.g. in calcite), but in general, translation-gliding which always produces small striations, can not be regarded as established until it has been proven that the striations are not the result of polysynthetic twin-gliding on a very minute scale.

EXPERIMENTAL METHODS FOR INVESTIGATION OF TRANSLATION-GLIDING

The softer and more plastic crystals usually require no special apparatus for the investigation of their gliding elements. This very susceptibility to deformation, however, sometimes causes great difficulty, since a very soft crystal will mold itself about and take an accurate impression of any instrument used to apply the deforming force. Thus, at least two opposite surfaces of the crystal will fail to reveal the attitude of the striations resulting from the gliding, because they are casts of the surfaces of the instrument and the substratum. In a later paper on the deformation of some of the alkali halides and related crystals, the writer will indicate several methods of investigating these softer substances.

On the other hand, hard crystals invariably cleave, part, or shatter if they are simply pressed, as in a vise. This difficulty can be easily overcome by embedding the crystal in some plastic medium. As the crystal is deformed, its deformation is resisted by the enclosing substance, which thus affords a pressure to counteract incipient parting. One of the simplest methods of attaining this end is that due to Kick; this has been fully described in an earlier communication.[10] The crystal is embedded in alum or some other plastic substance which has been introduced into a copper tube in a molten condition, and pressure is then applied axially to the tube and its contents.

Kick's method has several drawbacks: the bulging of the tube causes a certain unevenness of the forces acting on the crystal because the bulge is rarely symmetrical; the ductility of the copper prevents the application of very high retaining pressures; the experimental difficulties attending the emplacement of the crystal in the molten medium prevent fixing its orientation with desirable exactness; and finally, critical work with small crystals is practically impossible.

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[10] M. J. Buerger, The Plastic Deformation of Ore Minerals, I, *American Mineralogist*, **13**, 1928, pp. 4–5.

An apparatus ascribed to Tresca,[11] and used almost exclusively by Johnsen,[12] and later workers, is much more suitable for gliding investigations. A diagram of the writer's modified apparatus of this general design is shown in Figure 12. It consists essentially of a stout steel cylinder containing a one centimeter bore. One end of the bore is closed with a plug, and into the other is fitted a piston. Filling of the apparatus preparatory to deformation is accomplished as follows: precipitated sulfur[13] is packed into the plugged cylinder, and given an initial compacting by means of the piston, until it fills about half the bore. A shallow pit is scraped in the top of the compressed sulfur and a little new sulfur dusted therein to make a somewhat yielding base for the crystal. The crystal may then be lowered into the bore of the cylinder with a pair of forceps, set in approximate orientation on the sulfur base and centered. Final adjustments of orientation and centering can be accomplished while viewing the setting with the aid of a pair of binoculars sighted directly down the bore. When the crystal is satisfactorily set, more sulfur is dusted into the bore until full and

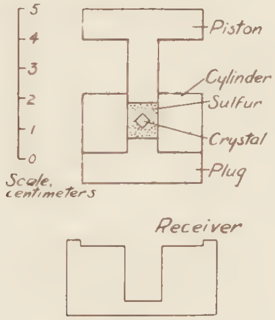

FIG. 12.

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[11] *Comptes Rend.*, **70**, 1870, p. 288.

[12] A. Johnsen, Einfache Schiebung an Lithiumsulfat-Monohydrat: *Neues Jahrb., B. B.*, **39**, 1914, p. 508.

[13] Sodium nitrate, later removable by solution in water, as well as the ether-soluble mercuric chloride, have also been used for this purpose.

carefully compressed with the piston. The last operation is repeated until just enough of the bore is unoccupied by the sulfur to allow the piston to be seated properly for starting the compression.

The compression, in the case of a relatively soft crystal, may be carried on in a large vise, but ordinarily a hand-driven testing machine with a capacity of some 50,000 pounds is desirable for deforming the harder crystals. After sufficient pressure has been applied, the plug is removed from the cylinder[14] and then replaced by the slug receiver. The apparatus is then again placed in the press, and the piston expels the hardened sulfur plug with its contained crystal. The latter may be removed for examination by solution of the enclosing sulfur in carbon disulfide.

With the aid of this apparatus crystals as small as a millimeter along an edge may be easily investigated, and no renewal of apparatus is necessary for successive tests.

THE CRITICAL DATA OF TRANSLATION-GLIDING

The accompanying table briefly lists the available critical data of translation-gliding. Only the information relating to crystals other than metals[15] have been included, and the writer hopes the list will be found to be reasonably complete. The classification adapted is, to some extent, arbitrary; it follows that of centro-symmetrical symmetry groups. For certain purposes it may appear desirable to regroup the data from a point of view of structural similarity but in the present state of knowledge this type of classification could not be carried to completion.

The information for minerals followed by an asterisk has been deduced from observations of natural occurrences and not from experiments.

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[14] This must be done with the aid of a vise and wrench. For this purpose it is desirable to have both plug and cylinder fitted with square flanges.

[15] A short resumé of our knowledge of translation-gliding in metals will be found in the publication: Cohesion and Related Problems, a general discussion held by the Faraday Society, November, 1927, especially the article by M. Polanyi: Deformation, Rupture, and Hardening of Crystals, p. 76.

Centro-symmetrical Group	Crystal	Equivalent Elements		Fundamental Elements		Translation sense if any	Observer	Reference
		t	*T*	*t*	*T*			
S_2 (triclinic)	Cyanite	1	1	[001]	(100)	?	Mügge	*Neues Jahrbuch*, **1898**, I, 81-82.
	$KMnCl_3 \cdot 2H_2O$	1	1	[101]	(010)	?	"	" " **1892**, II, 95-102.
	Aminoguanidine nitrate $CH_6N_4 \cdot HNO_3$	1	1	[001]	(010)	?	"	*Zeit. Krist.*, **71**, 1929, 70 73.
C_2^h (monoclinic)	Low-$KClO_3$	1	1	[100]	(001)	Counter-clockwise from $+b$	Fischer	*Neues Jahrbuch*, B.B., 32, **1911**, 37.
	$BaBr_2 \cdot 2H_2O$	1	1	[001]	(100)	Counter-clockwise from $+b$		" " **1889**, I, 145-160.
	Orpiment	1	1	[001]	(010)		Mügge	**1898**, I, 111-114.
	Vivianite	1	1	[001]	(010)		"	" " **1898**, I, 81.
	Erythrite	1	1	[001]	(010)		"	" " **1898**, I, 98.
	Sulfonal $(C_2H_5) \cdot (SO_2)_2C(CH_3)_2$	1	1	[010]	(100)		"	" " **1898**, I, 98-99.
	Lorandite	1	1	[010]	(10$\bar{1}$)		Siefert	*Centralblatt. f. Min.*, **1920**, 101.
	Miargyrite*	1	1	[010]	(100)		Mügge	*Neues Jahrbuch*, **1898**, I, 99.
	Gypsum	1	1	[001]	(010)		"	" " **1898**, I, 100-101
		1	1	Ca.[301]	(010)			
	Calcium butyrate	1	1	[010]	(001)		"	" " **1898**, I, 90-96.
	$Ca(C_4H_7O_2)_2$	1?	1?	[100]?	(001)?		"	*Zeit. Krist.*, **71**, 1929, 75.
	Barium butyrate	1?	1?	[010]?	(001)?			
	$Ba(C_4H_7O_2)_2$	1?	1?	[100]?	(001)?		"	" " **71**, 1929, 76.
	Pyroxene*	1?	1?	[001]?	(100)?	?	"	*Neues Jahrbuch*, **1898**, I, 114-118.
	Mica	1	1	[100]	(001)	?	"	" " **1898**, I, 102-108.
		2	1	[110]	(001)	?		
	Leadhillite	?	1	?	(001)	?	"	" " B.B.,14,**1901**,264.
	Wolframite*	?	1	?	(100)	?	"	" " **1898**, I, 150-151.
		?	1	?	(010)			

* Inferred from observation of natural occurrences; not experimental data.

CENTRO-SYMMETRICAL GROUP	CRYSTAL	NUMBER OF EQUIVALENT ELEMENTS		FUNDAMENTAL ELEMENTS		TRANSLATION SENSE IF ANY	OBSERVER	REFERENCE
		t	*T*		*T*			
C_2^h(Monoclinic continued)	$Li_2SO_4 \cdot H_2O$	?	1?	?	(100)?	?	Johnsen	*Neues Jahrbuch*, B.B., 39, **1914**, 515–516.
		?	1?	?	(301)?	?		
		?	2?	?	$(\bar{1}21)$?	?		
		?	1?	[101]?	$(\bar{1}01)$?	?		
		?	1?	?	$(\bar{3}01)$?	?		
V^h (orthorhombic)	Stibnite	1	1	[001]	(010)		Mügge	*Neues Jahrbuch*, **1898**, I, 77–79
	Bismuthinite	1	1	[001]	(010)		“	“ “ **1898**, I, 81.
	Guanajuatite	1	1	[001]	(010)		“	“ “ **1898**, I, 81.
	Manganite	1	1	[001]	(010)		“	*Centralblatt. f. Min.*, **1922**, 2.
	Aragonite	1	1	[100]	(010)		Veit	*Neues Jahrbuch*, B.B., 45, **1922**, 131–133.
	Columbite*	2	1	[101]	(010)		Mügge	“ “ **1898**, I, 147–150.
	Barite	1	1	[100]	(001)		“	“ “ **1898**, I, 151–152.
		2	2	$[0\bar{1}1]$	(011)	?	Veit	“ “ B.B., 45, **1922**, 128–131.
	Diammine zinc chloride	1	2	[001]	(110)		Mügge	*Zeit. Krist.*, **71**, 1929, 64–68.
	$(NH_3)_2ZnCl_2$	1	2	[100]	(011)			
	Anhydrite	1	1	[010]	(001)		Mügge	“ “ **1898**, I, 73–77.
		1?	2	[100]?	(012)	?	Veit	“ “ B.B., 45, **1922**, 133–135.
	Sulfur	2?	4	[110]?	(111)	?	Mügge	“ “ **1920**, 26–28.
	Bronzite*	1?	1?	[001]?	(010)?		“	“ “ **1898**, I, 114–118.
	Strontium butyrate	1?	1?	[010]?	(001)?		“	*Zeit. Krist.*, **71**, 1929, 77.
	$Sr\ (C_4H_7O_2)_2$	1?	1?	[100]?	(001)?			
	Epsomite	?	?	$[1\bar{1}0]$?	(110)?	?	Johnsen	*Centralblatt. f. Min.*, **1915**, 33–36.
		?	?	[010]?	(100)?			
		?	?	$[0\bar{1}1]$?	(011)?	?		
		?	?	$[\bar{1}01]$?	(101)?	?		
		?	?	$[\bar{1}02]$?	(201)?	?		

CENTRO-SYMMETRICAL GROUP	CRYSTAL	NUMBER OF EQUIVALENT ELEMENTS		FUNDAMENTAL ELEMENTS		TRANSLATION SENSE IF ANY	OBSERVER	REFERENCE
		t	T	t	T			
C_4^h (tetragonal)	Phosgenite	1	2	[001]	(110)		Taricco Mügge	*Atti. del Reale Acad. de Lincei*, **19**, 1910, 278–284. *Neues Jahrbuch*, **1914**, I, 43–48.
	Chalcopyrite	?	4	?	(111)	?	Mügge Buerger	" " **1920**, 30–31. *Am. Mineralogist*, **13**, 1928, 41–46.
C_3^i (hexagonal)	Dolomite	3	1	[01.0]	(00.1)		Johnsen	*Neues Jahrbuch*, **1902**, II, 139–144.
D_3^d (hexagonal)	Magnesite	3	1	[01.0]	(00.1)		Johnsen	*Neues Jahrbuch*, **1902**, II, 142.
	Siderite	3	1	[01.0]	(00.1)		"	" " " " "
	Rhodochrosite	3	1	[01.0]	(00.1)		Veit	" " B.B., 45, **1922**, 128
	Smithsonite	3	1	[01.0]	(00.1)		"	" " " " " "
	Calcite	3?	3?	[$\bar{1}$2.1] ≎[001] Miller	(01.2) ≎(110) Miller		Mügge	" " **1898**, I, 119–123.
	Graphite	3	1	[21.0]	(00.1)		Mügge	" " **1898**, I, 108–110.
	Brucite	3	1	?	(00.1)		Mügge	" " **1884**, I, 57. " " **1898**, I, 110–111.
D_6^h (hexagonal)	Ice	?	1	?	(00.1)		Mc Connel	*Proc. Roy. Soc.* **48**, 1890, 259–260. **49**, 1891, 323–343.
	Molybdenite	3	1	[21.0]	(00.1)		Mügge "	*Neues Jahrbuch*, **1895**, II, 211–228. " " **1898**, I, 110.

CENTRO-SYMMETRICAL GROUP	CRYSTAL	NUMBER OF EQUIVALENT ELEMENTS		FUNDAMENTAL ELEMENTS		TRANSLATION SENSE IF ANY	OBSERVER	REFERENCE
		t	*T*	*t*	*T*			
O^h (isometric)	Salamoniac	3	6	[001]	(110)		Johnsen	*Neues Jahrbuch*, **1902**, II, 149–153.
	Low-NH_4Br	3	6	[001]	(110)		“	“ “ “ “ “ “
	NaF†	3	6	[001]	(110)		Johnsen	“ “ **1902**, II, 148–149.
	Fluorite	6	3	[110]	(001)		Veit	“ “ B.B., 45, **1922**, 122–125.
	Galena	6	3	[110]	(001)		Mügge	“ “ **1898**, I, 123–138.
							Buerger	*Am. Mineralogist*, **13**, 1928, 6–11.
		3	3	[100]	(001)		Taricco	*Atti. della Reale Acad. de Lincei*, **19**, 1910, 508–511.
							Mügge	*Neues Jahrbuch*, **1914**, I, 48–51.
	Halite†	6	6	[$1\bar{1}0$]	(110)		Reusch	*Ann. der Physik und Chemie*, 132, **1867**, 443–444, and 449–450.
							Mügge	*Neues Jahrbuch*, **1898**, I, 138–145.
							Johnsen	“ “ **1902**, II, 146.
	Sylvite†	6	6	[$1\bar{1}0$]	(110)		Mügge	“ “ **1898**, I, 145.
	KBr†	6	6	[$1\bar{1}0$]	(110)		Johnsen	“ “ **1902**, II, 146.
							Ritzel	*Zeit. Krist.*, **52**, 1912–13, 275–276.
	KI†	6	6	[$1\bar{1}0$]	(110)		Johnsen	*Neues Jahrbuch*, **1902**, II, 146.
							Ritzel	*Zeit. Krist.*, **52**, 1912 13, 275–276.
	RbCl	6	6	[$1\bar{1}0$]	(110)		Johnsen	*Neues. Jahrbuch*, **1902**, II, 147.
	Periclase	6	6	[$1\bar{1}0$]	(110)		Mügge	“ “ **1920**, 29–30.
	High-NH_4I	6	6	[$1\bar{1}0$]	(110)		Johnsen	“ “ **1902**, II, 147–148.
	Sphalerite	?	4?	?	(111)?		Veit	“ “ B.B., 45, **1922**, 125–128.
							Buerger	*Am. Mineralogist*, **13**, 1928, 35–41.

† Incomplete or erroneous; new data to be published shortly.

A PECULIAR BLUE-GREEN AMPHIBOLE FROM THE METAMORPHIC IRON FORMATION OF THE EASTERN MESABI RANGE, MINNESOTA

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In the extreme eastern part of the Mesabi Iron Range of Minnesota an amphibole occurs which seems to be sufficiently peculiar, both in its optical properties and chemical composition, to deserve a special description. The exact location of its occurrence is near the now abandoned mining place Babbitt, southeast of its mining office, in the NW ¼ of section 17,T.60 N.,R.12 W. There the iron formation is in contact with granite and is highly metamorphosed. The blue-green amphibole is associated with grünerite and quartz and, in a few instances, with diopsidic pyroxene and garnet. At the contact the plagioclase and the quartz of the granite contain numerous inclusions of the amphibole.

As a rule, the amphibole is fibrous and forms a felty aggregate. Occasionally, however, well defined blades occur. These blades were well suited for optical examination and as the blue-green amphibole was free of grünerite and only associated and intergrown with quartz, a separation by means of heavy liquids and the electromagnet was possible and material of sufficient purity was thus obtained for chemical analysis.

Optical Properties

The amphibole has a strong pleochroism, X being light-yellow, Y peagreen, Z deep blue-green. This blue-green color is the most characteristic and distinctive property of the mineral. In sections, blades and fibres often have a curved appearance, the curves being almost semi-circular in shape. The extinction angle on (010) is about 16°. Accurate measurement is rendered difficult by poor cleavage.

The refractive indices for sodium light, measured by immersion liquids, were found to be as follows: $\alpha = 1.670, \beta = 1.690, \gamma = 1.696$ (all ± 0.001 to 0.002), optically negative. The axial angle is rather small for an amphibole. In sections and in fragments perpendicular to the acute bisectrix, the axes were always clearly visible at the edges of the field of view. Hence 2E must be about 100° and 2V about 54°.

CHEMICAL INVESTIGATION

The results of a chemical analysis on the purified material is shown in the following table.

ANALYSIS OF AMPHIBOLE FROM BABBITT, MINNESOTA

	Percentages	Ratios
SiO_2	48.76	.809
Al_2O_3	11.15	.109
Fe_2O_3	7.92	.049
FeO	21.72	.302
MnO	trace	
CaO	6.16	.110
MgO	0.38	.009
K_2O	0.58	.006
Na_2O	1.67	.027
H_2O*	1.89	.105
	100.23	

* Above 110°
Specific gravity 3.29.

The high percentage of silica is surprising. It is certainly not due to an admixture of quartz. Although an absolutely perfect separation of quartz from amphibole was impossible, repeated examination of the powder under the microscope showed that the adhering quartz was less than one per cent. This would reduce the indicated silica content less than one half of one per cent. Furthermore, the precipitate of silica was carefully tested for impurities and these subtracted, so that the given percentage is the portion of the precipitate which was soluble in hydrofluoric acid.

A recent X-Ray study of tremolite by B. E. Warren[1] seems to establish the composition of tremolite as $H_2Ca_2Mg_5(SiO_3)_8$. Furthermore, according to Warren, "Rotation photographs of cleavage fragments around the *c* axis of tremolite, kupfferite, actinolite, hornblende and grünerite show a remarkable similarity in both the positions and the intensities of the spots" (p. 57). Therefore, the probable constitution of any amphibole should be found by replacing some of the atoms of tremolite by those occurring in the respective amphibole, as suggested by Warren with regard to grünerite.

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[1] B. E. Warren, The structure of tremolite, $H_2Ca_2Mg_5(SiO_3)_8$, *Zeits. f. Krystallographie*, **72**, 1929, Heft 1, Sept., pp. 42–57.

Dr. A. N. Winchell, who called the writer's attention to this publication, was kind enough to calculate the molecules of the Babbitt amphibole, resulting possibly from such replacements. These calculations would give the following percentages of molecules:

2.1%	$H_2Ca_2Mg_5Si_8O_{24}$	
56.0%	$H_2Ca_2Fe_5Si_8O_{24}$	
5.6%	$H_2Fe_7Si_8O_{24}$	
26.1%	$H_2(Na, K)_2(Fe, Al)_4Si_8O_{24}$	(?)
10.2%	$H_2Al_{10}Si_4O_{24}$	(?)

After the formation of these molecules there still remains a small amount of alumina and the water content shows a slight discrepancy. Dr. Winchell writes: "I have suggested two molecules containing trivalent bases, but these are only tentative." It is to be hoped that the continued studies of Warren may also throw new light on the structure of the Babbitt amphibole.

No amphibole similar to the above is known to the writer. There is some remote similarity to the hudsonite of Cornwall, N. Y.,[2] "The pleochroism is pronounced . . . . and Z is green with a slight tinge of blue" (p. 229). The percentage of ferrous and ferric iron and of alumina is almost the same. The amount of lime and magnesia is somewhat greater. A considerable difference may be noted in the alkalis whose sum is 4.40% compared with 2.25% in the Babbitt amphibole. The percentage of silica, however, is much lower, 36.86% in the former and 48.76% in the latter.

Up to the present the amphibole is known only from Babbitt and seems to be restricted to the vicinity of the granite. It occurs frequently as a contact border. The writer saw it also two feet above the granite, while at a distance of four feet grünerite was the only amphibole present. Whether or not it occurs farther away from the intrusive mass cannot be decided at present. The mineral association will be dealt with more fully in the Journal of Geology.

Of frequent occurrence is another green amphibole with a bluish tinge in the metamorphosed iron formations of the Mesabi Range, of the Marquette district and of the Penokee area. This amphibole is either associated with grünerite or with monoclinic pyroxene.

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[2] S. Weidman, Note on the Amphibole Hudsonite previously called a Pyroxene. *Am. J. Sci.*, **15,** 1903, p. 227.

However, the blue shade is never so pronounced, nor is the axial angle as small as that of the Babbitt amphibole.

The writer wishes to express his sincere thanks to Dr. Clarence S. Ross for his kind assistance in isolating the amphibole, and to Dr. W. F. Foshag who made it possible for him to check certain determinations in the mineralogical laboratory of the U. S. National Museum. Finally thanks are due to Dr. A. N. Winchell for the recalculation of the chemical analysis.

ON THE HYDRATES OF SODIUM CARBONATE

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Sodium carbonate forms at least three stable hydrates, the mono-, hepta-, and decahydrates. Besides these there have been described a large number of other hydrates which are probably unstable. The existence of these other hydrates has been called into question by various writers.

In the course of some work on the system Na_2CO_3–K_2CO_3–H_2O the writer obtained several hydrates of sodium carbonate and is able to affirm definitely the existence of the hemipentahydrate $Na_2CO_3 \cdot 2\frac{1}{2}H_2O$.

This hydrate was first described by Morel[1] and has also been obtained by Professor W. C. Blasdale[2] who describes it as follows: "This salt usually separates in the form of needles but occasionally as long 4-sided or flattened 8-sided prisms terminated by a single pair of planes intersecting at 134°. The percentages of water in the different preparations were 31.04, 31.30, 32.10, 31.54, 29.90, and 30.46. Many samples contained potassium in the form of the carbonate up to 4%. The theoretical percentage of H_2O is 29.80 and the variations in its composition are due to a limited amount of solid solution formation."

In evaporating a solution of sodium and potassium carbonates in equimolecular proportion at 25°C several hydrates of sodium carbonate are the first crystalline products to form. If these crystals are left in contact with the solution and evaporation is continued a mass of the double salt $NaKCO_3 \cdot 6H_2O$ is finally obtained the earlier formed crystals again disappearing. If, however, some of the early crystals are removed the bulk composition is displaced and the double salt may fail to form.

At room temperature (ca. 18°) the first crystals are obtained at a concentration of about 21.3 mols each of K_2CO_3 and Na_2CO_3 to 1000 mols of water. These crystals are of some hitherto undescribed metastable hydrate of sodium carbonate which will not be further considered here. As evaporation continues the composition of the solution is displaced towards higher proportions of K_2CO_3, and $Na_2CO_3 \cdot 2\frac{1}{2}H_2O$ forms in good crystals from solutions over a wide range of concentrations. For instance, crystals of the hemipentahydrate were obtained from a solution having the composition 100.2 mols K_2CO_3 and 19.5 mols Na_2CO_3 per 1000 mols of H_2O.

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[1] J. Morel, Sur un nouvel hydrate de carbonate de sodium, *Bull. Soc. Fran. Min.*, vol. **12**, p. 546, 1889.

[2] W. C. Blasdale, *Jour. Am. Chem. Soc.*, vol. **45**, p. 2936, 1923.

CRYSTALLOGRAPHY

The crystals of $Na_2CO_3 \cdot 2\frac{1}{2}H_2O$ so obtained were very well developed. They were up to several centimeters in length, acicular and often in sheaf-like arrangement. Several of these crystals were measured on the two-circle goniometer. They were found to be orthorhombic and showed a strong development of the prism zone with four or five end faces. The forms (110), (010), (101) and (011) are always present. Several other forms, occur sporadically. In composition these crystals show the same variations mentioned by Blasdale.

The crystallography of this hydrate has been described by Morel.[3] The angles measured by the writer agree well with the axial ratio, $a:b:c=0.794:1:0.439$, given by him, as shown in table 1 comparing measured angles with angles calculated from the given axial ratio.

TABLE 1.

	Measured	Calculated
$101\wedge\bar{1}01$	57° 57′	57° 52′
$011\wedge0\bar{1}1$	47° 44′	47° 24′
$110\wedge1\bar{1}0$	76° 27′	76° 54′
$010\wedge011$	66° 17′	66° 18′
$010\wedge110$	51° 46′	51° 33′
$0\bar{1}0\wedge1\bar{1}0$	51° 47′	51° 33′

Wegscheider[4] has suspected that the crystals described by Morel belonged to the monohydrate. He points out that the angle $m:m=108° 6'$ given by Morel is probably due to a misprint and should be 103° 6′,[5] in which case it differs by only 2° 14′ from the corresponding angle for thermonatrite. There is no question that Wegscheider is correct in suspecting the misprint, but still the difference between the angles of the monohydrate and the hemipentahydrate is too great to allow his interpretation. The average value for the angle $110 \wedge 1\bar{1}0$ found on crystals of the hemipentahydrate was 76° 41′. This departs from the value given by Morel by 13′, whereas it departs from the value for thermonatrite by 2° 27′. It seems to the writer that the correctness of Morel's crystallographic data for the hemipentahydrate, having due regard for the aforementioned misprint, is thus well established.

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[3] J. Morel, *op. cit.*

[4] Notiz ueber die Hydrate des Natrium Carbonats, *Zeitsch. f. anorg. Chem.*, vol. **73,** p. 256–258, 1912.

[5] In modern usage this angle would be given as the supplement, 76° 54′.

Optical Examination

All crystalline products obtained during the present study were studied microscopically and it was found that the hemipentahydrate may be distinguished from the other products that can form from the solutions in question with great certainty. The optical properties of $Na_2CO_3 \cdot 2\frac{1}{2}H_2O$, determined in white light, were found to be the following:

Biaxial negative. Indices, determined in white light; $\alpha = 1.435$, $\beta = 1.492$, $\gamma = 1.547$; all ± 0.003. 2V large. Parallel extinction, negative elongation, $X = c$.

The stable hydrate at the temperatures in question is the decahydrate, natron. It was not obtained in the present experiments. Its indices, given by Larsen,[6] are:

$$\alpha = 1.405 \pm 0.003, \quad \beta = 1.425 \pm 0.003, \quad \gamma = 1.440 \pm 0.003.$$

It will be seen that there is hardly a chance for failure to differentiate between the two microscopically.

The monohydrate was obtained in the course of several trials and could easily be recognized microscopically. Its indices, as well as those of $Na.CO_3 \cdot H_2O$ from the J. T. Baker Chemical Company, were found to agree well with those given by Larsen[7] for the mineral thermonatrite; $\alpha = 1.420$ $\beta = 1.506$ $\gamma = 1.524$.

Density Relations

There exists, however, an error in the statement of the density of thermonatrite or of the artificial monohydrate which is repeated in nearly all the text and reference books. The density is given as 1.5–1.6. This is obviously much too low. Concerning this value Saslawsky[8] says: "Ich persoenlich bin nicht im Zweifel darueber dass das fuer $Na_2CO_3 \cdot H_2O$ in der Literatur angegebene spez.

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[6] E. S. Larsen, *U. S. Geol. Surv., Bull.* **679**, p. 114, 1921.

[7] *op. cit.*

[8] J. J. Saslawsky, Die Kontraktion der Minerale, *Zeitsch. f. Krist.*, vol. **59**, p. 193, 1923.

Gew., 1.5–1.6, nicht stimmt. Das betreffende spez. Gew. duerfte 2.1–2.3 sein."

The density of the monohydrate was determined by the pycnometer method with benzene to be 2.255 ± 0.002 at 16°C. This is in excellent agreement with the value, 2.235, calculated according to the law of Gladstone and Dale from the refractive indices using the values for "specific refractive energies" given by Larsen.[9]

The density of the hemipentahydrate was also determined using a pycnometer with methyl alcohol and found to be 2.053 ± 0.002. This also is in excellent agreement with the value, 1.981, calculated from the refractive indices.

Table 2 shows the relation between water content and density of the several hydrates of sodium carbonate. It may be seen that there is a regular decrease in density with increasing water content and that the values determined for the mono- and hemipentahydrate fall well into this series, whereas the value formerly given for the monohydrate would not agree at all with the other values.

TABLE 2.

	Weight percent H_2O	Density
Na_2CO_3	00.0	2.533[a]
$Na_2CO_3 \cdot H_2O$	14.5	2.255[b]
$Na_2CO_3 \cdot 5/2H_2O$	29.9	2.053[b]
$Na_2CO_3 \cdot 7H_2O$	54.3	1.510[a]
$Na_2CO_3 \cdot 10H_2O$	63.0	1.460[a]

[a] From the International Critical Tables.
[b] The writer's determination.

The hemipentahydrate of sodium carbonate obtained, as described above, from solutions also containing varying amounts of K_2CO_3 was reexamined after being kept in loosely stoppered bottles for three years. The crystals were still perfectly clear and yielded check results on being examined optically and measured on the goniometer.

Crystals of the hemipentahydrate were suspended in a clear solution of Na_2CO_3 at room temperature. The crystals continued to grow in this solution, and many new crystals in small needles also formed. Both proved to be the hemipentahydrate. At this temperature crystals of the decahydrate should be in equilibrium with a saturated solution of Na_2CO_3.

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[9] *op. cit.* p. 31.

The solution in contact with the hemipentahydrate at room temperature had a composition of 3.16 mols Na_2CO_3 per 1000 grams H_2O. The index of refraction of this solution is 1.389, determined in white light. At 20°C $Na_2CO_3 \cdot 10H_2O$ is in equilibrium with a solution containing 2.09 mols per 1000 grams of H_2O.[10] These observations agree with Morel's report that he had obtained the hemipentahydrate from very concentrated solutions of solvay soda between 18° and 25°C.

In summary it may be pointed out that several observations agree in indicating the existence of the hemipentahydrate of sodium carbonate as a phase quite distinct from the monohydrate, thermonatrite. These are:

1. Analyses of the material.[11]
2. Crystallographic data which are characteristic.
3. Optical data which enable its recognition.
4. Density determination in agreement with calculated value.
5. Relation of density to densities of related hydrates in agreement with expectation.

[10] International Critical Tables.

[11] Blasdale, *op. cit.*

NOTES AND NEWS

ANALYSES AND DERIVATIONS OF TWO BEACH SANDS FROM THE HOLSTEINSBORG DISTRICT OF GREENLAND*

DUNCAN STEWART, JR., *Brown University.*

INTRODUCTION

There have been three University of Michigan Expeditions into the Holsteinsborg District of southwest Greenland. Dr. William H. Hobbs of the University of Michigan was the Director of the expeditions. It was on the third expedition, during the summer of 1928, that the author collected two samples of interesting beach sands.

The sands were collected at opposite ends of a six hundred and twenty-five foot beach, some twenty-five miles from the edge of the inland ice, on the north shore of the Söndre Strömfjord in the Holsteinsborg District. The beach was at the foot of a terrace composed of glacial materials, and was flanked by out-crops of metamorphic rocks. The origin of the majority of the grains of the beach was found to be in these metamorphic rocks. The terrace material would add little to the beach, except possibly during the spring tides and very stormy weather.

MINERAL CHARACTERISTICS OF THE SANDS

A garnet-magnetite-hornblende sand, (Sand No. 1), was found at the western end of the beach. These loose detrital materials graded into a feldspar-quartz sand within three hundred feet, and at the eastern extremity of the beach a sample of the feldspar-quartz sand, (Sand No. 2), was collected.

METHOD OF STUDY. An average sample of each sand was screened, and a solution of bromoform, (sp. gr. 2.71), was used to float off the feldspar and quartz. The concentrates were washed, and examined under the binocular microscope. The minerals were separated according to color, degree of rounding, cleavage and fracture, and were placed in small vials, for later examination with the petrographic microscope. Approximately 17,800 grains of Sand No. 1 and 7350 grains of Sand No. 2 were used in the calculations of the percentages of the mineral constituents. Slides were made of each of the mineral types.

PARENT ROCKS. The rocks which contributed grains to the garnet-magnetite-hornblende sand are, in order of their importance: (a) *garnetiferous-hornblende gneiss*, (b) *biotite gneiss*, and (c) *feldspar-quartz pegmatites*. The garnetiferous hornblende gneiss is a metamorphosed igneous intrusive into the biotite gneiss. The pegmatites cut the biotite gneiss.

A thin section of the *garnetiferous-hornblende gneiss* shows, in order of abundance: green hornblende, quartz, almandite, oligoclase, orthoclase, magnetite, titanite, zircon, pyrite, pennine, sericite, and kaolin.

A thin section of the biotite gneiss exhibits the following minerals, in order of abundance: quartz, orthoclase, oligoclase, biotite, microcline, titanite, muscovite, apatite, zircon, pennine, epidote, sericite, and kaolin. The orthoclase is the most abundant feldspar, and the oligoclase is present in approximately half the quantity of the orthoclase.

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* Published with permission of the Director of the expeditions.

The rocks which contributed material to the feldspar-quartz sand, (Sand No. 2), are, in order of their abundance: (a) *granodiorite gneiss*, (b) *hornblende gneiss*, and (c) *feldspar-quartz pegmatites*. The granodiorite gneiss is the main rock from which this sand was derived.

A thin section of the granodiorite gneiss exhibits the following minerals, in order of abundance: oligoclase, quartz, orthoclase, microcline, magnetite, titanite, epidote, zircon, apatite, pennine, sericite, kaolin, leucoxene, and limonite. The plagioclase is the most abundant mineral in the section, and the quartz is in slight excess of the orthoclase. The epidote is seen to have a yellowish tinge between parallel nicols. (This is, also, true of the epidote in the sand.)

Derivation of the Sands. In Sand No. 1 the greater part of the garnet was derived, undoubtedly, from the garnetiferous-hornblende gneiss, as were the following constituents: magnetite, green hornblende, ilmenite, diopside, zircon, pyrite, rutile, calcite, chlorite, oligoclase, and some of the quartz and titanite. The biotite gneiss contributed, in order of importance: quartz, feldspar, tourmaline, titanite, epidote, andalusite, biotite, and muscovite. The pegmatites were the source of some of the tourmaline, quartz, and feldspar. The galena and some of the calcite were derived, most probably, from small veins in the immediate vicinity of the west end of the beach.

In Sand No. 2 the feldspar and the quartz were derived mainly from the granodiorite gneiss. The excess of the plagioclase over the quartz and orthoclase in the thin section is reflected in the sand, as shown by the percentages of the constituent grains. The epidote, titanite, zircon, muscovite, and chlorite, have their origins in this rock. The remaining minerals in the sand came from the hornblende gneiss, with the possible exception of some of the tourmaline, which came, most probably, from the pegmatites.

Certain well-rounded quartz grains were possibly brought to the beach on the fjord from the outwash plain in front of the Russell Glacier by the Watson River. However, this constituent may have been brought down from a sand flat some few miles to the east of the bay. The rounding may be the result of wind action. In the analysis of the 25,000 grains, used in calculating the percentages of the mineral constituents, only 10 of this type were noted.

The plate accompanying the article shows the relative sizes and shapes of a few of the type grains of Sand No. 1.

Summary and Conclusions

Sand No. 1 contains the following minerals, in order of abundance: garnet, magnetite, green hornblende, ilmenite, tourmaline, feldspars, (plagioclase, orthoclase, microcline.), quartz, diopside, titanite, epidote, zircon, andalusite, pyrite, galena, rutile, calcite, biotite, chlorite, and muscovite. These loose detrital materials came from the following metamorphic rocks, in the order of importance: (a) garnetiferous-hornblende gneiss, (b) biotite gneiss, and (c) feldspar-quartz pegmatites.

Sand No. 2 contains the following minerals, in order of abundance: feldspar (plagioclase, orthoclase, microline), quartz, green hornblende, garnet, tourmaline, biotite, epidote, magnetite, diopside, ilmenite, titanite, zircon, calcite, muscovite, and chlorite. These grains were derived from the following metamorphic rocks, in the order of importance: (a) granodiorite gneiss, (b) hornblende gneiss, and (c) feldspar-quartz pegmatites.

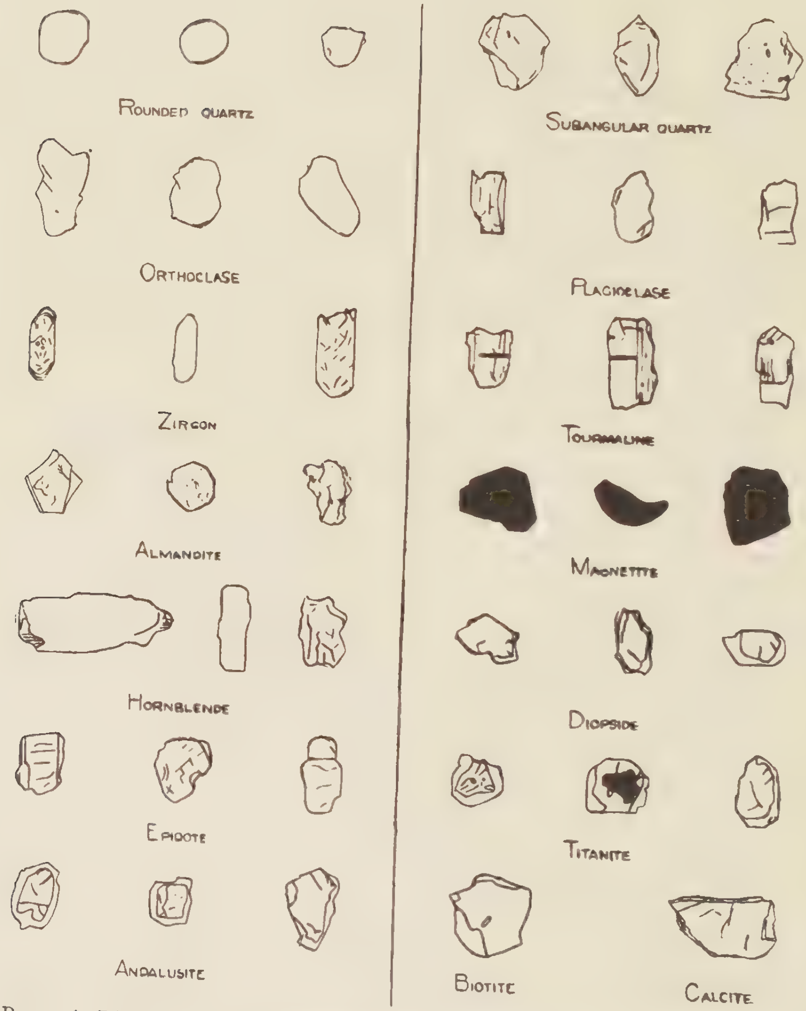

PLATE 1. Diagrams of some mineral grains showing relative sizes and shapes. Sand No. 1 (×20).

Acknowledgments

The author is indebted to Professor Bradford Willard and to Mr. Alonzo Quinn for the reading and criticizing of the above article. Mr. B. R. Millington photographed the plate.

THE MINERALS AND THE PERCENTAGES OF THE CONSTITUENTS OF THE SANDS

Sand No. 1.

1. Garnet........ 38.366 %
   *(a) Medium red.
   (b) Pink.
   (c) Wine red.
   * In order of importance.
2. Magnetite............22.837
3. Hornblende (Green)...19.420
4. Ilmenite.............. 8.447
5. Tourmaline........... 5.541
   (a) Brown.
   (b) Yellowish (rare)
6. Feldspar............. 2.608
   (a) Orthoclase (25%)
   (b) Microcline (rare)
   (c) Plagioclase (75%)

97.219+%

The remaining 2.780+% is made up of the following minerals, their percentages on the basis of 100%.

7. Quartz...............46.677%
   (a) Subangular.
   (b) Well-rounded. (rare)
8. Diopside.............21.474
9. Titanite..............12.560
10. Epidote.............. 7.293
11. Zircon............... 6.888
12. Andalusite............ 2.106
13. Pyrite................ 1.539
    (a) Unaltered. (rare)
    (b) Altered.
14. Galena................ 0.324
15. Rutile................ 0.162
16. Calcite............... 0.162
17. Biotite............... 0.081
18. Chlorite.............. 0.081
19. Muscovite............ 0.081

Gneiss fragments.......... 0.972

Total 100.400%

Sand No. 2.

1. Feldspar.............68.175 %
   (a) Orthoclase. (35%)
   (b) Microcline. (rare)
   (c) Plagioclase. (60%)
2. Quartz...............27.270
   (a) Angular. (common)
   (b) Subangular. (")
   (c) Well-rounded. (rare)
3. Hornblende (Green)... 3.967

99.412+%

The remaining 0.587+% is made up of the following minerals, their percentages on the basis of 100%.

4. Garnet...............37.209 %
   (a) Pink.
   (b) Medium red.
5. Tourmaline...........34.888
   (a) Brown.
   (b) Yellowish. (rare)
6. Biotite............... 9.309
7. Epidote.............. 6.976
8. Magnetite............ 6.976
9. Diopside............. 4.651

Total 100.009 %

The following minerals are found as traces in sand No. 2.

10. Ilmenite.
11. Titanite.
12. Zircon.
13. Calcite.
14. Muscovite.
15. Chlorite.

Mineral grains found in Sand No. 1, but absent in Sand No. 2 are: (a) andalusite, (b) ilmenite, (c) pyrite, (d) galena, (e) rutile, and (f) wine-red garnet.

A MINERALOGICAL EXAMINATION OF BLACK SAND FROM NOME CREEK, ALASKA

Albert S. Wilkerson, *Alaska School of Mines, College, Alaska.*

Very few mineralogical examinations have been made of black sands associated with the gold-placers of Alaska. The writer knows of no previous quantitative mineralogical examination of black sands from Nome Creek, Fairbanks Mining District, Alaska. The writer had the opportunity to study the sands from Nome Creek, and this article is the outcome of his studies.

A moment's thought regarding the time, expense, and labor involved in making any quantitative chemical analysis of such elements as tungsten, tin, titanium, zirconium, and platinum, will make it evident how very important a preliminary mineral examination is, where these rare elements are involved. It is, however, unnecessary to state that the detection of small values of platinum can be accomplished only by regular assay methods.

The method employed in examining the black sands may be briefly summarized as:

1. Drying.
2. Sizing with screens.
3. Separation into fractions with the aid of an electro-magnet.
4. Examination of these fractions.

Drying. The sand was placed in a suitable dish and allowed to stand in a warm location, gently heating at times, until all moisture was driven off. This prevented the sand particles from adhering to one another and also to the magnet.

Sizing. The sand was shaken and mixed thoroughly so as to get a representative sample. This was screened through a 20 to a 30-mesh (to the inch) sieve, yielding a size nicely suited for use with an electro-magnet, as well as being representative of the average size of the sand particles. It was also a size well suited to megascopic identification of the minerals.

Separating. After weighing 200 grams of the size chosen, it was divided into several parts, each part in turn was spread out very thinly on a smooth-surfaced board. The board was then placed in the field of a strong electro-magnet. As dried sand whose particles were approximately the same size was used, sharp magnetic fractions were obtained by varying the distance, previously determined by using known mineral mixtures, between the board and the terminals of the magnet.

Repetition of such treatment resulted in fractions consisting practically of a single mineral species. As magnetic fractions often owe their impurity to included or adhering grains, these fractions were later studied in detail by means of a hand lens, and by testing their various physical properties. A few wet tests were always used to supplement other tests.

The minerals determined in the magnetic fractions were the following: magnetite, and with it as films, or adhering to it in minute quantities, were hematite and limonite; ilmenite; wolframite; pyrrhotite; and garnet (small percentage of the garnets, however).

The non-magnetic portion of the sand was next studied. Small portions were successively gone over with a hand lens. The physical properties of the various constituent minerals were used to identify them, using, as was done with the magnetic portion, wet tests where identification was in question.

The minerals identified in the non-magnetic portion were the following: feldspar, garnet, quartz, zircon, pyrite and marcasite, cassiterite, hematite and limonite, galena, and scheelite. Mica schist was about the only rock constituent of the sand.

The weight of the various mineral constituents and their respective percentages are here listed:

	Name of Mineral	Weight in Grams	Percentages (corrected to 100%)
1	magnetite with little hematite and limonite	80.0174	40.81
2	garnet	40.5902	20.69
3	schist	22.1110	11.27
4	pyrite and marcasite	20.1994	10.30
5	quartz	18.2652	9.31
6	wolframite	9.7780	4.99
7	scheelite	4.1868	2.13
8	feldspar	0.3116	0.16
9	cassiterite	0.2110	0.11
10	ilmenite	0.1550	0.08
11	pyrrhotite	0.1090	0.06
12	zircon	0.0816	0.05
13	galena	0.0718	0.04
		196.0880 grams	100.00%

A large percentage of the minerals was sub-angular to angular in shape, signifying that the sand had not been transported any great distance.

No minerals of economic importance in commercial quantities were detected. Minerals of economic importance not in commercial quantities, that were found are: cassiterite, wolframite, and scheelite—the main tin and tungsten ores of the world. There was only 0.11% of cassiterite and 7.12% of the tungsten minerals. These minerals cannot be extracted from sands at profit, but the presence of these minerals points favorably to lodes of the same minerals at a not far distant point.

The writer has not had the opportunity to visit the region of the headwaters of Nome Creek, but various reports of the United States Geological Survey, dealing with the Mineral Resources of Alaska, state that intruded into the pre-Ordovician schists of this region are various granitic rocks. It is in these intrusives at the headwaters of Nome Creek that the writer would place the source of the tungsten minerals found in the black sands.

Alaska, and the United States as a whole, are not favored with an abundance of tungsten minerals or of cassiterite. The Alaskan prospector knows gold, silver, copper and lead when he sees them, but few of the prospectors know cassiterite in its various forms, and fewer still know the tungsten ores. The Alaska School of Mines twice a year trains prospectors in various essential fields, including an extensive training in recognizing minerals and methods of determining unknown minerals.

It is the hope of the writer that the attention of the prospectors of Alaska will be drawn to other minerals of importance while on their untiring search for gold. The rare minerals are here in Alaska. Some of them have been found and others will be found in the future. A mineralogical examination of numerous black sands from numerous parts of the Territory would not be entirely amiss.

DUMORTIERITE IN RIVERSIDE COUNTY, CALIFORNIA

F. Mac Murphy, *California Institute of Technology, Pasadena.*

An occurrence of dumortierite, heretofore undescribed so far as known, is in the vicinity of the Cajalco tin mine, property of the American Tin Corporation, approximately 13 miles southwest of Riverside, California. Apparently the mineral is rather widespread in the region, as suggested by a specimen collected by Charles Anderson from a point four miles northeast of Corona.[1] The dumortierite occurs in a granodiorite country rock whose chief constituents in apparent order of abundance are: orthoclase, oligoclase, quartz and biotite. The rock is hypidiomorphic granular, coarse textured and rich in quartz. Accessory minerals are titanite, magnetite and apatite. The rock generally carries more or less tourmaline, especially near each of the numerous well-defined tin-bearing tourmaline-quartz veins on the property.

Dumortierite was noted in several localities, scattered through the rock in rose-lavender or orchid splotches. Occasionally fine rosettes of dumortierite can be seen in the hand specimen but usually the splotches have more the appearance of rose quartz. Microscopically, it is evident that a small amount of dumortierite gives the rock a pronounced coloration. Quartz is the predominant constituent in the dumortierite rock and generally forms a coarse grained mosaic. Other minerals occurring in varying proportions are: tourmaline, zircon, apatite, corundum (?), muscovite, sericite, and either cassiterite or rutile. Quartz is often crowded with inclusions of apatite, quartz, radiating fibres of dumortierite and a few shreds of apparently primary biotite. Structurally the dumortierite is in fanshaped radiating masses, spherulitic aggregates, fibres, or prismatic crystals. Commonly the rosettes have been altered to sericite with only a fringe of dumortierite remaining. In this occurrence the structural arrangement of the sericite plates coincides with those of the dumortierite. In some cases, however, it appears that these minerals are contemporaneous.

The following optical determinations were made with the Leitz Universal stage. An approximate basal section was placed truly perpendicular to the axis of the microscope, giving therefore the acute negative bisectrix, α. The axial angle (2 H) was then measured directly with a glass segment of index 1.649 as 40°, and from this 2V was calculated as 39°. The thickness of the section was accurately determined on adjacent quartz grains as 0.022 mm., and by compensator $(\gamma-\beta)$ was determined as 0.0034.

On sections parallel to the side pinacoid $(\gamma-\alpha)$ was determined as 0.026. From these values for the differences of the indices and the Mallard formula, 2V was calculated as 39° 30′ (–). With the ordinary stage and a near basal section $2H_a$ by conoscope is 44° 30′, measured in cedar oil ($n=1.516$). From the values of H in cedar oil and the glass hemisphere, β was calculated as 1.685 (average). The more accurate value by immersion was found to be 1.690. The conoscope value of $2H_a$ (44° 30′) gives $2V=39.6°$, and the segment value (40°) gives $2V=39°$.

On the section normal to Bx_a the axial plane lay in the longer diagonal of the four prism planes bounding the base, i.e., γ was parallel to the longer crystal axis $\breve{b}$ and not $\breve{a}$. This is contrary to the published optical orientation where γ is said to be $=\breve{a}$.

Pleochroism tested with the ocular dichroscope on a section of about 0.022 mm. thickness gives parallel alpha (c), eosine pink, amaranth pink or light rosolane purple (Ridgway's colors); and parallel to β and γ colorless.

Professor John E. Wolff has contributed the study by the Universal stage.

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[1] Dumortierite, *Bull. of the Mackay School of Mines Staff, University of Nevada*, Vol. **XXII,** p. 10, 1928.

According to figures compiled by the Minerals Division of the Department of Commerce, the manufacture of motor cars and trucks in 1928 absorbed 18 percent of the domestic production of rolled steel, 14.6 percent of the production of copper, 25.6 percent of the lead produced from domestic ores, 24.1 percent of the tin deliveries, 27.7 percent of the production of aluminum, 4.5 percent of the zinc, and 28 percent of the domestic consumption of nickel.

The production of German potash in 1928 was equivalent to 1,690,000 tons of K_2O, an increase of 11.4% over that of the previous year. Of this amount 38.8% was exported and 61.2% was consumed at home. The sales for 1928 showed an increase of 14.7% over 1927.

Analyses by the U. S. Geological Survey of the cores of two test holes drilled in Texas showed several beds of polyhalite of potential commercial value and in addition, in the twelfth hole, other salts such as carnallite ($KCl\cdot MgCl_2\cdot 6H_2O$), sylvite ($KCl$), langbeinite ($K_2SO_4\cdot 2\ MgSO_4$), and kieserite ($MgSO_4\cdot H_2O$). These minerals have also been found in New Mexico but thus far only polyhalite ($K_2SO_4\cdot MgSO_4\cdot 2\ CaSO_4\cdot 2\ H_2O$) has appeared in public tests in Texas. At present it is not clear whether one continuous formation extends into both States or whether the area in Texas represents a separate deposit.

Horace Bushnell Patton, professor emeritus of the Colorado School of Mines, died July 15, 1929, age 72 years.

E. K. Gedney and Harry Berman have recently described in *Rocks and Minerals* an unusual occurrence of large beryl crystals in a feldspar quarry at Albany, Maine. The crystals occur in radial aggregates in some cases attaining a length of 17 to 18 feet and a diameter of from 3 to 4 feet. It is estimated that approximately 100 tons of beryl are now exposed. This occurrence undoubtedly represents the largest single deposit of this mineral as yet found in this country.

Mr. Samuel G. Gordon of the Philadelphia Academy of Natural Sciences has spent three months in Bolivia collecting minerals; sixty-three cases of specimens have already arrived at the Academy. He will likewise spend considerable time in South Africa, mainly in the Congo.

A CORRECTION. In the September 1929 issue of the American Mineralogist page 340, the chemical formula of the new mineral tanteuxenite was erroneously given as $YtTaO_8$. It should be $YtTi_2TaO_8$. Dr. E. S. Simpson has kindly called attention to the error.

PROCEEDINGS OF SOCIETIES

NEW YORK MINERALOGICAL CLUB

Minutes of the November Meeting

A regular monthly meeting of the New York Mineralogical Club was held at the American Museum of Natural History on the evening of Wednesday, Nov. 20, 1929, with the president, Dr. Herbert P. Whitlock, in the chair. Fifty persons were present.

Mr. Valentine Abrogast of Wingdale, N.Y., Mr. Augustus B. Krug of New York City, Dr. M. W. Senstius of Ann Arbor, Mich., and Mr. H. T. Strong of Chatham, N. J., were elected to membership.

The speaker of the evening was Prof. R. J. Colony of Columbia University, who addressed the Club on "*The Geology of Southeastern Wyoming*," with particular reference to the territory surrounding the summer camp maintained jointly by Columbia University and the University of Wyoming.

The oldest rocks in this region are a complex series of pre-Cambrian metamorphosed sediments, which have been invaded by a large granite bathylith. The latter forms the Laramie and the Medicine Bow mountains. On the eroded surface of the granite rest Pennsylvanian and Cretaceous sediments, which have been folded into synclines and form the Laramie Basin and similar valleys. Tertiary sediments lie unconformably upon these rocks.

Mr. Morton reported upon a successful trip held by the Club to the quarries at West Paterson and Prospect Park, N. J., on Election Day, Nov. 5th. About 29 mineral species were collected. The trip was noteworthy for the unusually fine bornite found at the Prospect Park quarry.

HORACE R. BLANK, *Secretary.*

NEWARK MINERALOGICAL SOCIETY

At the annual meeting of the Newark Mineralogical Society the following officers were elected for the year 1929–30:

President: John A. Grenzig
Vice-President: Geo. E. Carpenter
Secretary: H. L. Thowless
Treasurer: H. M. Lehman

A short meeting was held at which the President brought to the attention of the members the fact that access to the Paterson quarries could no longer be obtained due to indiscretions of some collectors. The meeting then adjourned to the auditorium where Mr. L. H. Bauer, of the New Jersey Zinc Company, spoke on the "*Minerals of Franklin, New Jersey.*" The physical characters of the minerals were demonstrated by means of several ultra-violet light machines, owned and operated by Mr. Broadwell and Mr. Reamer. Mr. Bauer and Mr. Broadwell exhibited the new find "barylite." When exposed to the ultra-violet light this species has the property of showing a blue fluorescence similar to that of scheelite. Among the many specimens shown was willemite from northern Rhodesia, this possesses a green fluorescence of paler color than that of the Franklin material.

RODNEY B. MILLER, *Secretary.*

MINERALOGICAL SOCIETY OF GREAT BRITAIN AND IRELAND

MINERALOGICAL SOCIETY, *November* 6.—*Anniversary Meeting.*—Dr. G. T. Prior in the chair.

DR. C. E. TILLEY: *On Scawtite, a new mineral from Scawt Hill, Co. Antrim* (*with chemical analysis by Mr. M. H. Hey*). This new monoclinic mineral, with composition $6CaO\cdot 4SiO_2\cdot 3CO_2$, occurs in the contact zone between the chalk and tertiary dolerite, from which another new mineral, *larnite*, was recently described (*Min. Mag.*, vol. **22**, p. 77).

Dr. F. Coles Phillips: *On the composition-plane of* (010)*-twins in the acid plagioclases.* In the true pericline twin, the inclination of the variable composition-plane for different compositions is correctly given by Wülfing's curve. T. Barth's conclusion that there is no regular variation is not justifiable, and results partly from confusion with other twin-laws. The pericline twin should be of frequent occurrence in the crystalline schists.

Mr. M. H. Hey: *On the variation of optical properties with chemical composition in the Rhodonite-Bustamite series.* A complete optical study of three analyzed members of the Rhodonite-Bustamite series, together with the data available from the literature, shows regular variation in the optical properties and specific gravity with change in lime content.

Dr. F. Coles Phillips: *A preliminary account of some mineralogical and chemical changes induced by progressive metamorphism in the Green Bed group of the Scottish Dalradian.* Analyses prove the Green Beds to be a truly isochemical series in respect to the constituents significant in progressive metamorphism. The earliest-formed plagioclase is pure albite, but a progressive entry of the anorthite molecule can be traced. The adjustment to equilibrium is apparently close, all the reconstituted plagioclase of a given rock having the same composition. In the highest grades the feldspar is a medium andesine. Similar variations with increasing grade are found in the associated epidiorites. The earliest-formed greenish micaceous mineral is shown to be a true potash mica, which undergoes increase in FeO in higher grades. Hornblende appears in the chlorite zone only in rocks low in potash.

W. Campbell Smith, *General Secretary*

NEW MINERAL NAMES

NEW DATA

Eggonite

J. Krenner: Mineralogische Mitteilungen aus Ungarn. (Mineralogical Contributions from Hungary.) *Centr. Mineral., Geol.*, Abt. A, pp. 34–38, **1929.**

Chemical Properties: A hydrous aluminum phosphate and not a silicate of cadmium as originally described.

Crystallographic Properties: Orthorhombic. $a:b:c=0.87749:1:0.53694$. Forms: *a*(011), *m*(110), *a*(100), *b*(010), (451). Habit prismatic. Cleavage parallel to (100), good.

Physical and Optical Properties: Biaxial negative, $2V=60°34'$. $\beta=1.5901$. Plane of the optic axes parallel to *b*(010). Dispersion $\rho>\nu$.

Occurrence: Found at Felsobanya (not Altenberg as originally described) with miargyrite and diaphorite.

Discussion: Suggested to be the aluminum analogue of strengite.

W. F. Foshag

Fizelyite

Reported in Appendix III, p. 30 (1915), *Dana System of Mineralogy;* described by J. S. Krenner and J. Loczka. *Math. Természettud Értesitö*, **42,** pp. 18, 19, 21, 1926.

Name: After the mining engineer Sándor Fizély by whom the mineral was found.

Chemical Properties: Formula approximately: $5PbS \cdot Ag_2S \cdot 4 Sb_2S_3$. Analysis gave: Sb 34.02, As 0.32, Pb 37.48, Ag 7.70, Fe 0.62, S 20.10, insol. 0.30. A sulphantimonite of lead and silver.

Physical Properties: Color dark lead-gray or steel-gray. Occurs as striated prisms with no terminal faces. Said to be monoclinic in crystallization. (*Dana*, Appendix III, p. 30.) Very brittle, H=2. Cleavage (010).

Occurrence: Found with semseyite at Kisbánya, Co., Szatmár, Hungary.

J. F. Schairer

DISCREDITED SPECIES

Thermokalite

K. W. Earle, *Proc. Geol. Assoc. London*, Vol. **39**, p. 96, 1928, mentions "a large number of specimens of thermokalite, a new member of the haloid group, which has, apparently, so far escaped description." This previously unpublished name was copied from Dr. H. J. Johnston-Lavis' manuscript labels. L. J. Spencer, Eleventh list of new mineral names, *Min. Mag.*, **21**, p. 579, 1928, lists the name thermokalite. F. A. Bannister, The so-called "thermokalite" and the existence of sodium bicarbonate as a mineral, *Min. Mag.*, **22**, 53–64, 1929, shows that the material labeled "thermokalite" by Johnston-Lavis is a mixture of trona, thermonatrite, sodium bicarbonate (nahcolite) and thenardite. The material was from a tunnel near Stufe di Nerone, Baja. The name thermokalite should be dropped from mineralogical nomenclature.

J. F. Schairer

Louisite

T. L. Walker: On the nature of Louisite. *Contributions to Canadian Mineralogy*, 1923, *Univ. of Toronto Studies, Geol. Ser.*, No. **16**; *Proc. Trans. Nova Scotian Institute Sci.*, **16**, 35–7, 1927. Louisite was first described by Honeyman (*Proc. Nova Scotian Inst. Nat. Sci.*, **5**, 15, 1878). The mineral was closely related to apophyllite in composition except that it was much higher in silica. Walker re-examined the type specimen in the Provincial Museum at Halifax. A thin section showed that louisite is "an aggregate of radiating spherules of quartz in cleavable apophyllite." The "louisite" was crushed and separated by heavy liquids into quartz and apophyllite contaminated with quartz. The apophyllite separated had the usual optical properties of that mineral. The name louisite should be dropped from mineralogical nomenclature.

J. F. Schairer

Lehrbachite, Zorgite

George Frebold: Über einige selenerze und ihre Paragenesen im Harz. (Some selenium ores and their paragenesis in the Harz.) *Centr. Min., Geol.*, **1927A**, pp. 16–32.

The selenium minerals of the Harz (Lehrbach, Zorge and Tilkerode) are clausthalite (PbSe), tiemannite (HgSe), naumannite (Ag_2Se), umangite (Cu_3Se_2).

Lehrbachite proves to be a mixture of clausthalite and tiemannite. Zorgite = clausthalite and umangite with minor amounts of tiemannite. Tilkerodite = clausthalite, cobaltite, an unknown constituent and hematite.

W. F. Foshag